AC Plasma Display Panel

FIELD OF THE INVENTION

The present invention relates to an alternate current (AC) plasma display panel (hereinafter called a panel) used for an image display of a television receiver or an information display terminal.

BACKGROUND OF THE INVENTION

Fig. 10 shows a conventional panel and its driving apparatus. On panel 1, sustaining discharge generated between pairs of scan electrodes and sustain electrodes causes a phosphor to emit light for display. 2M rows of pairs of scan electrodes SCN_j and sustain electrodes SUS_j (j = 1 to 2M) and N columns of data electrodes D_i (i = 1 to N) arranged orthogonally to them constitute a matrix with 2M rows and N columns. Discharge cells are formed at intersections between data electrode D_i and pairs of scan electrode SCN_j and sustain electrode SUS_j. Over panel 1, pairs of scan electrodes SCN_j and sustain electrodes SUS_j are pulled out reversely to each other. The scan electrodes in any adjacent rows are pulled out reversely to each other over the panel. The sustain electrodes in any adjacent rows are pulled out reversely to each other over the panel.

In other words, scan electrodes SCN_1, SCN_3, ... SCN_{2M-1} in odd-numbered rows are pulled out to the left side of panel 1 and connected to scan electrode driving circuit 2a for driving them. Sustain electrodes SUS_1, SUS_3, ... SUS_{2M-1} in odd-numbered rows are pulled out to the right side of panel 1 and connected to sustain electrode driving circuit 3a for driving them. Scan electrodes SCN_2, SCN_4, ... SCN_{2M} in even-numbered rows are pulled out to the right side of panel 1 and connected to scan electrode driving circuit 2b for driving them. Sustain electrodes SUS_2, SUS_4, ... SUS_{2M} in even-numbered rows are pulled out to the

left side of panel 1 and connected to sustain electrode driving circuit 3b for driving them. Data electrodes D_1, ... D_N are pulled out to the upside of panel 1 and connected to data electrode driving circuit 4 for driving them.

When a sustain pulse voltage for causing the sustaining discharge is applied on the sustain electrodes or scan electrodes on panel 1, pulse currents having extremely short time-width that do not contribute to light emission run~~s~~ through respective rows, and therefore electromagnetic waves occur in respective rows. Because the currents in any adjacent rows run reversely to each other, the electromagnetic waves have reverse polarities and cancel each other.

However, when an operation of scan electrode driving circuit 2a is out of accord with that of scan electrode driving circuit 2b, an operation of sustain electrode driving circuit 3a is out of accord with sustain electrode driving circuit 3b. And applying time of the sustain pulse voltages in any adjacent rows even slightly out of accord with each other, time of generating pulse currents is out of accord with each other and therefore the electromagnetic waves do not cancel each other. As a result, the electromagnetic waves are radiated out of the panel and cause the other electronic apparatus to malfunction.

For preventing the electromagnetic wave from being radiated out of the panel, it is considered that all scan electrodes SCN_1 - SCN_{2M} and sustain electrodes SUS_1 - SUS_{2M} are pulled out in the same direction, for example, on the left side of the panel and connected to the scan electrode driving circuit and the sustain electrode driving circuit respectively. In this case, currents which are the same in ~~an~~ amplitude run reversely through the scan electrode and the sustain electrode in each row, and the electromagnetic waves generated by reversely running currents therefore cancel each other. As a result, the electromagnetic waves are not radiated out of the panel.

In this case, however, the sum of the path length through which the

current runs from the scan electrode driving circuit to a discharge cell and the path length through which the current runs from the discharge cell to the sustain electrode driving circuit ~~varies~~ vary depending on a position of the discharge cell in the panel. In other words, the current running path length to the discharge cell on the right side of the panel is smaller than that on the left side. Therefore, due to voltage drop caused by resistance of electrodes, a voltage applied between the scan electrode and the sustain electrode for each discharge cell varies depending on the discharge cells. Since strength of the discharge varies for each cell, brightness irregularity occurs.

SUMMARY OF THE INVENTION

An alternate current (AC) plasma display panel that hardly generates an electromagnetic wave and has good display quality without brightness irregularity is provided.

The plasma display panel comprises two substrates arranged ~~putting~~ with a discharge space therebetween, and scan electrodes, sustain electrodes, and conductors adjoining one another in row over one substrate. When a sustain pulse voltage is applied between the scan electrodes and the sustain electrodes, an electromagnetic wave with polarity reverse to an electromagnetic wave generated by currents running through the scan electrodes and the sustain electrodes is generated on the conductors. The electromagnetic wave emitted from the currents running through the scan electrodes and the sustain electrodes cancels that from the current running through the conductors.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic block diagram of an alternate current (AC) plasma panel and a driving apparatus in accordance with embodiment 1 of the present

invention.

Fig. 2 is a partial perspective view of a panel in accordance with example 1 of embodiment 1 of the present invention.

Fig. 3 shows driving time-chart of the panel in accordance with example 1 of embodiment 1 of the present invention.

Fig. 4 shows a partial electrode array of the panel and a driving apparatus in accordance with example 1 of embodiment 1 of the present invention.

Figs. 5A, 5B, and 5C show a pulse voltage applied to electrodes over the panel and sustaining discharge currents in accordance with example 1 of embodiment 1 of the present invention.

Figs. 6A and 6B show a sectional view of a part of a panel in accordance with example 2 of embodiment 1 of the present invention.

Figs. 7A and 7B show a partial, sectional view of another constitution of the panel in accordance with example 2 of embodiment 1 of the present invention.

Fig. 8 is a schematic block diagram of a panel and a driving apparatus in accordance with embodiment 2 of the present invention.

Fig. 9 shows a partial electrode array of the panel and the driving apparatus in accordance with embodiment 2 of the present invention.

Fig. 10 is a schematic block diagram of a conventional panel and its driving apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(Preferred embodiment 1)

Fig. 1 shows an alternate current (AC) plasma display panel and its driving apparatus in accordance with embodiment 1 of the present invention. In Fig. 1, 2M rows of pairs of scan electrodes SCN_j and sustain electrodes SUS_j (j

= 1 to 2M) form display electrodes over panel 5. N colmns of data electrodes D_i (i = 1 to N) are arranged orthogonally to ~~them.~~ the scan electrodes and sustain electrodes In other words, scan electrode SCN_j and sustain electrode SUS_j adjoining each other constitute a row and data electrodes D_i constitutes a column. A discharge cell is formed at an intersection of each row and each column, and 2M × N discharge cells are formed in a matrix shape. In addition, in each row, conductor CW_j in parallel with scan electrode SCN_j and sustain electrode SUS_j is arranged adjacent to sustain electrode SUS_j without being put by scan electrode SCN_j and sustain electrode SUS_j, and these three electrodes constitute one set. Conductor CW_j is electrically connected to sustain electrode SUS_j. In Fig. 1, scan electrode SCN_j, sustain electrode SUS_j, and conductor CW_j are arrayed in this order in each row. However, they may be arrayed in the order of conductor CW_j, sustain electrode SUS_j, and scan electrode SCN_j, or in the order of conductor CW_j, scan electrode SCN_j, and sustain electrode SUS_j.

Scan electrodes SCN_1 - SCN_{2M} are connected to scan electrode driving circuit 6 on the left side of the panel. Conductors CW_1 - CW_{2M} are respectively connected electrically to sustain electrodes SUS_1 - SUS_{2M} on the right side of the panel and connected to sustain electrode driving circuit 7 on the left side of the panel. Data electrodes D_1 - D_N are connected to data electrode driving circuit 4 on the upside of the panel.

Fig. 2 is a partial perspective view of panel 5 of example 1. A plurality of scan electrodes 10 (SCN_j), sustain electrodes 11 (SUS_j), and conductors 12 (CW_j) which are covered by dielectric layer 9 are disposed over insulating substrate 8 in the row direction, and protective coat 13 is placed on dielectric layer 9. Each scan electrode 10 is constituted with transparent electrode 10a and bus 10b overlapping on electrode 10a, and, each sustain electrode 11 is constituted with transparent electrode 11a and bus 11b overlapping on electrode 11a. A

resistance of the transparent electrodes is generally high, and the ~~bus~~ buses, made of silver or the like, are overlapped on the transparent electrodes~~, resistance~~. Resistance as the scan electrodes is thus lowered. Conductor 12 is formed by a lower-resistance material made of silver or the like.

A plurality of data electrodes 15 (D_i) are disposed over insulating substrate 14 in the column direction, and barrier rib 16 in parallel with data electrode 15 is arranged between the data electrodes 15. Phosphor 17 is placed on the surface of data electrode 15 and the side surface of barrier rib 16. Insulating substrate 8 and insulating substrate 14 are arranged facing to each other. Discharge space 18 surrounded by insulating substrate 8, insulating substrate 14, and barrier rib 16 is filled with discharge gas containing xenon and at least one of helium, neon, and argon.

The panel performs sustaining discharge between each pair of scan electrode 10 and sustain electrode 11. For preventing false discharge between conductor 12 in any row and scan electrode 10 in its adjoining row, a distance between conductor 12 and scan electrode 10 in its adjoining row is long enough.

A method for driving the panel in accordance with embodiment 1 of the present invention is hereinafter described. Fig. 3 shows driving time-chart of an operation of the panel. The operation is described with reference to Fig. 1 through Fig. 3.

First, during a writing period, sustain electrode driving circuit 7 maintains all sustain electrodes SUS_1 - SUS_{2M} to 0 (V) through conductors CW_1 - CW_{2M}. During scanning the first row, ~~when~~ positive writing pulse voltage +Vw (V) is applied from data electrode driving circuit 4 to data electrode D_i corresponding to a discharge cell for performing display in data electrodes D_1 - D_N. Negative scan pulse voltage –Vs (V) is applied from scan electrode driving circuit 6 to scan electrode SCN_1 in the first row, and then writing discharge occurs at the

discharge cell at the intersection of data electrode D_i and scan electrode SCN_1. By scanning from the second row to 2M-th row similarly to scanning the first row, writing discharge occurs at discharge cells for performing display.

During a sustaining period subsequently to the writing period, sustain electrode driving circuit 7 applies negative sustain pulse voltage –Vm (V) to all sustain electrodes SUS_1 - SUS_{2M} through conductors CW_1 - CW_{2M}. In the discharge cells where the writing discharge occurs, the initial sustaining discharge occurs between scan electrode SCN_j and sustain electrode SUS_j, and a sustaining discharge current runs from scan electrode driving circuit 6 to sustain electrode driving circuit 7 through scan electrode SCN_j, sustain electrode SUS_j, and conductor CW_j. Then, sequentially, scan electrode driving circuit 6 and sustain electrode driving circuit 7 alternately apply negative sustain pulse voltage –Vm (V) to all sustain electrodes SUS_1 - SUS_{2M} and scan electrodes SCN_1 - SCN_{2M} through conductors CW_1 - CW_{2M}, respectively. Thus, the sustaining discharge continues between scan electrode SCN_j and sustain electrodes SUS_j in the discharge cells where the writing discharge occurs. In addition, the sustaining discharge current from sustain electrode driving circuit 7 to scan electrode driving circuit 6 through conductor CW_j, sustain electrode SUS_j, and scan electrode SCN_j, and the sustaining discharge current from scan electrode driving circuit 6 to sustain electrode driving circuit 7 through scan electrode SCN_j, sustain electrodes SUS_j, and conductor CW_j alternately run. Light emitted by this continuing sustaining discharge is used for display.

Subsequently, during an erasing period, sustain electrode driving circuit 7 applies negative narrow-width cancellation pulse erasing voltage –Ve (V) to all sustain electrodes SUS_1 - SUS_{2M} through conductors CW_1 - CW_{2M} to generate an erasing discharge and to stop the sustaining discharge. By the operation discussed above, whole screen of the panel is displayed.

Effects of the panel and its driving apparatus are hereinafter described.

Fig. 4 shows an electrode array in the (2j-1)-th and 2j-th rows, namely, a part of the panel shown in Fig. 1. In Fig. 4, a current running when the sustain pulse voltage is firstly applied during the sustaining period is represented by arrows. Fig. 5A, Fig. 5B, and Fig. 5C show a wave form of the sustain pulse voltage and currents at this time. Fig. 5A shows the voltage wave form at scan electrode SCN_{2J-1} with reference to sustain electrode SUS_{2J-1} when sustain electrode driving circuit 7 applies negative sustain pulse voltage –Vm (V) to sustain electrode SUS_{2J-1}. Fig. 5B shows a wave form of the current running from scan electrode driving circuit 6 through scan electrode SCN_{2J-1} and sustain electrode SUS_{2J-1}. Fig. 5C shows a wave form of the current running through conductor CW_{2J-1}. Here, a current direction from the left side to the right side of the panel is positive.

As shown in Fig. 5B and Fig. 5C, the sustaining discharge current running when the sustain pulse voltage is applied comprises current Id and current Ic. Current Id is a discharge current contributing to actual light emission, and slowly runs with a little delay from applying the sustain pulse voltage. Current Ic runs through a capacitor formed by the scan electrode and the sustain electrode, namely a capacitive current, has a sharp peak wave form with a very narrow time-width, is useless for the light emission, and generates an electromagnetic wave. For convenience of explanation, time scale on the left half is set different from that on the right half in Fig. 5..

As shown in Fig. 4, the sustaining discharge current (shown by thick solid line arrows) running from scan electrode driving circuit 6 through scan electrode SCN_{2j-1} and sustain electrodes SUS_{2j-1} reaches sustain electrode driving circuit 7 through conductor CW_{2j-1} shown by thick dashed line arrows. In other words, as shown in Fig. 5B and Fig. 5C respectively, the current running through scan

electrode SCN_{2j-1} and sustain electrode SUS_{2j-1} and the current running through conductor CW_{2j-1} have the same amplitude and run in the reverse directions. In addition, these current wave forms synchronize with each other. Therefore, electromagnetic waves generated from these currents have reverse polarities and cancel each other.

A situation similar to the above discussion occurs for continuously generated sustaining discharge. The electromagnetic wave released by the current running through a pair of scan electrode SCN_{2j-1} and sustain electrode SUS_{2j-1} and the electromagnetic wave released by the current running through conductor CW_{2j-1} respectively have reverse polarities and cancel each other. Therefore, the electromagnetic wave radiated out of the panel is suppressed, and the other electronic apparatus is prevented from malfunctioning.

Scan electrode SCN_{2j}, dielectric layer 9, and conductor CW $_{2J-1}$ form a capacitor because dielectric layer 9 is formed between scan electrode SCN_{2j} and conductor CW_{2j-1}. When sustain pulse voltage –Vm (V) is applied to conductor CW_{2j-1}, a capacitive current runs through this capacitor. Because the capacitive current (shown by thin dashed line arrows) running through the capacitor runs from scan electrode driving circuit 6 through scan electrode SCN_{2j} and conductor CW_{2j-1} to sustain electrode driving circuit 7, the capacitive currents which are the same in ~~an~~ amplitude run simultaneously in the reverse directions with respect to each other. The electromagnetic wave released by the capacitive current running through scan electrode SCN_{2j} and the electromagnetic wave released by the capacitive current running through conductor CW_{2j-1} respectively have reverse polarities and cancel each other.

The electromagnetic waves generated by the sustaining discharge currents running through the (2j-1)-th row and the 2j-th row are canceled, respectively. And the electromagnetic wave generated by the capacitive current running

between the (2j-1)-th row and the 2j-th row are canceled. The electromagnetic waves generated by the currents respectively running between the (2j-1)-th row and the (2j-2)-th row and between the 2j-th row and the (2j+1)-th row are cancelled. Therefore, the electromagnetic waves generated by the currents running through the (2j-1)-th row and the 2j-th row are perfectly canceled.

Effects for the electrodes in the (2j-1)-th row and the 2j-th row are discussed above, but it is clear that electrodes in the other rows also have similar effects. During the sustaining discharge, the current running through scan electrode SCN_j and sustain electrode SUS_j and the current running through conductor CW_j simultaneously run in reverse directions. The electromagnetic wave generated by the current running through scan electrode SCN_j and sustain electrode SUS_j and the electromagnetic wave generated by the current running through conductor CW_j respectively have reverse polarities and thus perfectly cancel each other. The currents run in reverse directions respectively through conductor CW_j in any row and through scan electrode SCN_{j+1} in its adjacent and next row, and therefore, the electromagnetic wave generated by the currents is canceled by itself. As a result, radiation of the electromagnetic wave out of the panel is restrained.

In the panel in accordance with this embodiment, the sum of the path length through which the current runs from scan electrode driving circuit 6 to a discharge cell and the path length through which the current runs from the discharge cell to sustain electrode driving circuit 7 is constant independently upon a position of the discharge cell in the panel. Therefore, voltage applied between the scan electrode and the sustain electrode is substantially the same for each discharge cell. As a result, the sustaining discharge with substantially the same strength occurs in each discharge cell, and brightness irregularity is hardly observed.

Fig. 6 shows a panel in accordance with example 2 of embodiment 1 of the present invention. Fig. 6A and Fig. 6B are respectively a sectional view at position 6A-6A and a sectional view at position 6B-6B of the panel in Fig. 2. In this panel, barrier 19 is disposed on dielectric layer 9 in a region between rows. In other words, in the panel of example 1, barrier 19 is disposed on dielectric layer 9 between adjacent conductor 12 and scan electrode 10 in adjacent rows. Barrier 19 is shown by a solid line in Fig. 6. Barrier 19 may be also disposed across rows from the end of sustain electrode 11 in any row to the end of scan electrode 10 in its next row, as shown by the dashed line in Fig. 6A. Due to barrier 19, an electric field in discharge space 18 between conductor 12 and scan electrode 10 in adjacent rows is remarkably weakened when a voltage is applied between conductor 12 and scan electrode 10. As a result, false discharge is further certainly prevented between rows, namely, between conductor 12 and scan electrode 10.

As shown in Fig. 7A and Fig. 7B, barrier 19 may have a double-cross shape where it has not only the part in the row direction discussed above but also a substantially piled on barrier rib 16 in the column direction. In this panel, an electric field in discharge space 18 between conductor 12 and scan electrode 10 in the adjoining row is remarkably weakened. As a result, the false discharge is further certainly prevented between conductor 12 and scan electrode 10 in the adjoining row.

In addition, barrier 19 is made of photo-absorptive material, and reflected external light is therefore suppressed to increase contrast of the panel. As this photo-absorptive material, mixture of ruthenium oxide, manganese dioxide, chromium oxide, or nickel oxide to a glass material similar to that in dielectric layer 9 or the like can be used.

In embodiment 1 of the present invention, an example where a scan

electrode driving circuit is connected to scan electrodes, and a sustain electrode driving circuit is connected to conductors coupled to sustain electrodes is described. Also, by electrically connecting the conductors to the scan electrodes, connecting the scan electrode driving circuit to the conductors, and connecting the sustain electrode driving circuit to the sustain electrodes, a current running through the scan electrodes and the sustain electrodes and current running through the conductors may run in reverse directions.

(Preferred embodiment 2)

Fig. 8 shows a panel and its driving apparatus in accordance with embodiment 2 of the present invention. In Fig. 8, panel 20 differs from panel 5 of embodiment 1 in arrangement and the connecting of scan electrode SCN_j, sustain electrode SUS_j, and conductor CW_j. In odd-numbered rows, they are arranged in the order of scan electrode SCN_j, sustain electrode SUS_j, and conductor CW_j, and in even-numbered rows, they are arranged in the order of conductor CW_j, sustain electrode SUS_j, and scan electrode SCN_j. Conductor CW_j and sustain electrode SUS_j are electrically interconnected. Scan electrodes SCN_1 - SCN_{2M} are connected to scan electrode driving circuit 6 on the left side of the panel, and conductors CW_1 - CW_{2M} are electrically connected to sustain electrodes SUS_1 - SUS_{2M} on the right side of the panel and connected to sustain electrode driving circuit 7 on the left side of the panel. Data electrodes D_1 - D_N are coupled with data electrode driving circuit 4 on the upside of the panel.

In panel 20, scan electrode SCN_{2j} and SCN_{2j+1} to which same voltage are applied are adjoining each other between the even-numbered row and the odd-numbered row. Distance between any adjoining scan electrodes is set as wide as possible. Thus, when scan pulse voltage sequentially applied to the scan electrodes in a writing operation generates a writing discharge between the data

electrode and the scan electrode in the even-numbered row. The discharge is prevented from a false discharge between the scan electrode in the odd-numbered row following the scan electrode in the even-numbered row and the data electrode.

The driving method for panel 20 is same as the driving method of embodiment 1 described using the operation driving time-chart in Fig. 3. Effects of the panel and a driving apparatus of embodiment 2 of the present invention will be described.

Fig. 9 is an electrode arrangement diagram of the (2j-1)-th and 2j-th rows as a part of the electrode arrangement of panel 20 shown in Fig. 8. Fig. 9 shows a sustaining discharge current running in the initial sustaining discharge during a sustaining period. A sustaining discharge current running from scan electrode driving circuit 6 through pair of scan electrode SCN_{2j-1} and sustain electrode SUS_{2j-1} runs through conductor CW_{2j-1} toward sustain electrode driving circuit 7. The direction of the sustain discharge current (shown by thick solid arrows) running through scan electrode SCN_{2j-1} and sustain electrodes SUS_{2j-1} is opposite to that of the current (shown by thick dotted arrows) running through conductor CW_{2j-1}. Because these currents are supplied from one of scan electrode driving circuit 6 and sustain electrode driving circuit 7 in the repeatedly continuing sustaining discharge, they always simultaneously run in reserve directions. Therefore, during the sustaining discharge, an electromagnetic wave released by the current running through pair of scan electrode SCN_{2j-1} and sustain electrode SUS_{2j-1} and an electromagnetic wave released by the current running through conductor CW_{2j-1} respectively have reverse polarities and thus perfectly cancel each other. In addition, for example, scan electrode SCN_{2j-2} in any ~~low~~ row and scan electrode SCN_{2j-1} in the next row, sustain electrode SUS_{2j-1} ~~and conductor CW_{2j-1}~~, and conductor CW_{2j-1} and

conductor CW_{2j} respectively are at the same voltage, and therefore always no capacitive current runs between each pair of them. As a result, no electromagnetic wave is generated from these parts, and total electromagnetic wave does not radiate out of the panel.

Effects for the electrodes the (2j-1)-th and 2j-th rows are discussed above. However, effects for the other rows are similar, and radiation of the electromagnetic wave out of the panel is suppressed.

By forming a barrier rib similar to that described in embodiment 1 on dielectric layer 9 between scan electrodes adjoining each other, the writing discharge generated in a row is prevented from a false discharge in its adjoining row.

In the panel and the driving apparatus of embodiment 2 of the present invention, the scan electrode, the sustain electrode, and the conductor are arranged in the order of the scan electrode, the sustain electrode, and the conductor in each odd-numbered row, and in the order of the conductor, the sustain electrode, the scan electrode in each even-numbered row. Also, they may be arranged in the order of the conductor, the sustain electrode, and the scan electrode in each odd-numbered row, and in the order of the scan electrode, the sustain electrode, and the conductor in each even-numbered row, oppositely to that in each odd-numbered row. The current running through the scan electrodes and the sustain electrodes and the current running through the conductors run respectively in the reverse directions, even when the conductors are electrically connected to the scan electrodes, the scan electrode driving circuit is connected to the conductors, and the sustain electrode driving circuit is coupled to the sustain electrodes,

Examples where a conductor is arranged in each row are described in the embodiments discussed above. However, one conductor may be arranged for plural rows of scan electrodes and sustain electrodes, and total current running

through these scan electrodes and sustain electrodes may run through the conductor. For example, one conductor may be disposed at the end of the panel, and total current running through all scan electrodes and sustain electrodes may run through the conductor. In this case, the canceling effect of the electromagnetic waves is weakened comparing with the case where one conductor is disposed in each row, but depending on size of the panel, radiation of the electromagnetic wave out of the panel is suppressed in a range where other apparatuses are not affected.

Technology discussed above can be applied to an AC plasma display panel having a constitution other than that of the AC plasma display panel used in the embodiments of the present invention or a driving method other than the exemplary driving method.